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LDPC Coded Adaptive AF Scheme Based on MI Model

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Abstract

User Cooperation is a promising technology to obtain diversity gain at terminals. According to the traditional amplify-and-forward (AF) scheme, relay node help to transmit source node's information with fixed transmission power all the time. It is not optimal in view of power efficiency, especially when the channel state is good. This paper introduces the adaptive AF scheme based on the Mutual Information (MI) model. The optimal power to relay is predicted accurately. The reliability requirement is satisfied, and the power is saved for transmitting new information. Theoretical analysis and simulation results indicate that the adaptive AF scheme improves the power efficiency significantly.

Keywords: user cooperation; decode-and-forward; mutual information model

1. Introduction

Cooperative communication among users was proposed by A. Sendonaris et al. in 1998 [1], the idea of which is that user terminals share their antennas to form a virtual Multi-Input and Multi-Output (MIMO) system to acquire diversity gain. J. N. Laneman et al. proposed Amplify-and-Forward (AF) and Decode-and-Forward (DF) [2] schemes to realize cooperative communication in 2001. Then, coded cooperation was proposed by T. E. Hunter et al. in 2002 [3]. In the three cooperation modes, AF makes Relay Node (RN) help to transmit the codeword of Source Node (SN) to Destination Node (DN) whenever RN received SN's codeword. So it is the scheme with lowest complexity. When the channel states of the S-R link is pretty good, the AF scheme is quite practical.

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However, the traditional AF scheme fixes the transmitting power of relayed modulation symbols at RN. Obviously, it is not a good choice for the power efficiency of the whole system. When the channel state of the R-D link is good, it is enough for RN to relay with lower transmission power to meet the reliability requirement of DN. This paper proposes an adaptive AF scheme, based on the mutual information (MI) model [4], the optimal power to relay is predicted precisely, the saved energy can be used to transmit new information. The MI model is a multi-carrier link error prediction model proposed by Lei Wan et al. [4]. It has been confirmed to be suitable for turbo/LDPC/convolutional coded multi-state system [5, 6]. It is promising in multi-carrier, multi-time-slot and multi-antenna systems.

The rest of the paper is organized as follows. Section II describes the three-node model of the adaptive AF scheme. Section III introduces the MI model in brief. The proposed adaptive AF scheme is described in detail in section IV. Finally, The error performance and efficiency of the proposed and the traditional schemes are compared and analyzed in section V.

2. System Model

The system model of fixed and adaptive AF scheme is a three-node model, including SN, RN and DN. The AF Scheme includes two stages. In the first stage, SN broadcasts LDPC codeword to RN and DN. If RN received it successfully, it prepares to transmit it in the next stage. When DN failed to decode the codeword, in the second stage, RN relays the received codeword to DN. As long as SN and RN are far enough from each other, the S-D and R-D link can be viewed as incoherent from each other. DN combines the incoherent code words from SN and RN, obtaining diversity gain to improve the performance.

3. The Mutual Information Model

The diagram of the MI model is illustrated in fig. 1, including two separate sub-models: the modulation sub-model and the coding sub-model. They are independent, the modulation sub-model merely relates to the demodulation algorithm and modulation order, while the coding model only relies on AWGN performance of the decoding algorithm, coding rate and block size.

What can be observed in fig. 1 is the parameter passed from modulation model to coding model is modulated symbol-level mutual information (SI) of all the sub-carriers, each SI corresponds to a SNR state during one coding block. For *M*-ary modulation, with modulation order m, the SI of the channel symbol SNR value is defined as

$$
\begin{aligned}
SI(\gamma,m) &= E_{XY}\left\{\log_2\frac{P(Y\,|\,X,\gamma)}{\sum_X P(X)P(Y\,|\,X,\gamma)}\right\} \\
&= E_X\left\{\int_{Y_R=-\infty}^{+\infty}\int_{Y_I=-\infty}^{+\infty} P(Y\,|\,X,\gamma)\cdot\log_2\frac{P(Y\,|\,X,\gamma)}{\sum_X P(X)P(Y\,|\,X,\gamma)}\,dY_I Y_R\right\}
\end{aligned} \tag{1}
$$

Where the modulated symbol X belongs to a certain modulation constellation, and the received symbol $Y=(Y_R+i*Y_I)$. We assume $P(X)=1/M$ as the a priori probability of $\boldsymbol{X}$ in this paper. $P(Y\,|\,X,\gamma)$ is the probability density function of $\boldsymbol{Y}$ conditioned on the noise-free channel symbol $\boldsymbol{X}$ and parameterized by channel state γ.

The coding model consists of two parts: the SI collection/correction unit and the quality mapping unit. The SI collection/correction unit first collects the received coded bit information (RBI) among the J symbols, whose SNR values are $\{\gamma_1,\gamma_2,\ldots,\gamma_J\}$, with the modulation order $\{m_1,m_2,\ldots,m_J\}$:

$$RBI_{\mathrm{MI}} = \sum_{j=1}^{J} SI(\gamma_j, m_j) \tag{2}$$

It is normalized by the number of total coded bits N to the Received coded Bit Information Rate (RBIR) by

$$RBIR_{\mathrm{MI}} = RBI_{\mathrm{MI}} / N \tag{3}$$

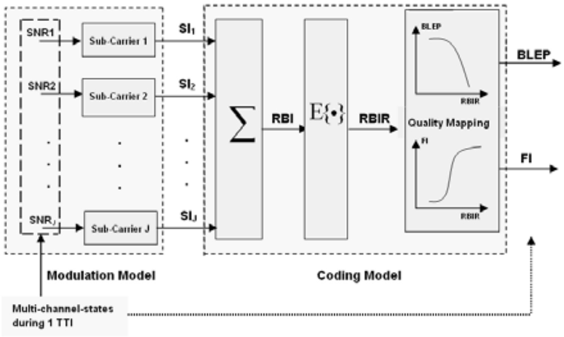

Fig. 1. The Diagram of the Mutual Information link quality model structure

4. The Adaptive AF Scheme based on the MI Model

4.1. The two Look Up Tables (LUTs) based on the MI Model

Our previous work in [5] has confirmed that the MI model is capable of unifying BLEP performance of various modulation schemes and diverse sub-carrier states, and even different coding block length that the IEEE802.16e standard specified. Thus it will be accurate enough to implement LA with two LUTs, one is built according to the RBIR vs. BLEP performance of BPSK modulation and different coding rates over AWGN channel, as fig. 2(a) shows. The other is the Effective SINR-to-RBIR mapping table based on (1), (2) and (3) for the four modulation modes, as illustrated in fig. 2(b).

4.2. The Adaptive AF Scheme based on the MI Model

The relayed codeword is actually a copy of the LDPC codeword transmitted from SN to DN. The MI model calculates the lacked information for the DN to decode with the BLER lower than the target BLER after the S-D transmission finished. Then RN compensates for it with relayed power.

Specifically, assuming the required instantaneous block error rate (BLER) is no more than $BLER_{\mathrm{target}}$, according to the LUT1, for a specific coding rate, the $RBIR_{\mathrm{target}}$ is clear. When the broadcasting stage is finished, the MI model checks the mutual information received by DN, donating the instantaneous channel state of the S-D link by $SINR_{\mathrm{SD}}$, then according to the LUT2, the $RBIR_1$ is known, if the instantaneous BLER at DN is higher than $BLER_{\mathrm{target}}$, $RBIR_1$ must be less than $RBIR_{\mathrm{target}}$. And the lacked mutual information is $N^*(RBIR_{\mathrm{target}}-RBIR_1)$, these should be compensated by RN. With the same codeword, $RBIR_2=RBIR_{\mathrm{target}}-RBIR_1$, according to the LUT2, $SINR_{\mathrm{RD}}$ can be found out, thus the power factor for relaying can be calculated.

ln(BLER)	coding rate								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-0.1	RBIR values								
-0.2									
-0.3									
……									
-1									
-1.1									
……									
-2									
-2.1									
……									
-3									
-3.1									
……									
-7									

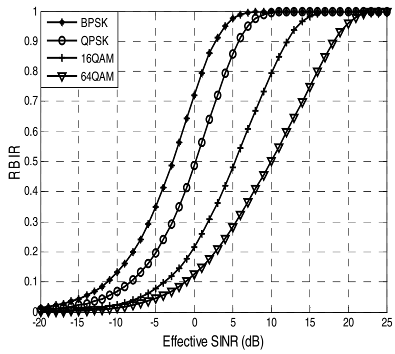

Fig. 2. (a) LUT1: RBIR vs. BLEP; (b) LUT2: Effective SINR vs RBIR

5. Simulation Result

To verify the performance of the adaptive AF scheme, the link-level simulation platform is constructed according to the three-node system model. The error-correcting code is the (576,288) LDPC code specified by IEEE802.16e standard. The S-R link, S-D and R-D links are all single Rayleigh block fading channel. They are independent from each other. The average signal-to-noise ratio (SNR) of the S-D link and the R-D link is the same. And RN should retransmit the codeword it received from SN as long as DN fails to decode the codeword. For the fixed AF scheme, RN retransmits the codeword with the same power as SN. However, in the adaptive AF scheme, RN retransmits the codeword with a power factor predicted by the MI model, which is a relative value that the power used to relay divided by the total power of RN, namely, assuming the total power of RN is 1, then the power factor ranges from 0 to 1. If RN needn't relay the codeword, the power factor equals 0. If RN used the same power as SN transmitting the codeword, the power factor is 1. If RN relay the codeword with part of power, the power factor is the ratio of the relayed power to the total power. And the rest power is saved.

The error performance of the adaptive AF scheme should be compared with the traditional AF scheme. Assuming the worst BLER of the system should not be higher than 0.01. Only the BPSK modulation scheme is used. For the (576, 288) WiMax LDPC code, the retransmission power is set as 1 for the traditional AF scheme, and that of the adaptive AF scheme ranges from 0.1 to 1, which is predicted by the MI model. The BLER performance of the adaptive AF scheme, the traditional AF scheme and the no cooperation scheme are illustrated in fig. 3(a). And the corresponding relative ratios of relayed modulation symbols are shown in fig. 3(b).

It can be observed that when the SNR of S-D link is lower than -5dB, the BLER performance of the adaptive AF scheme and that of the traditional AF scheme is almost the same, and both are higher than 0.01. That is because the channel state is so bad that even if the entire power of RN are used to retransmit the codeword of SN, the reliability requirement can still not be satisfied.

When the SNR of S-D link is from -4.5dB to -2dB, the BLER performance of the adaptive AF scheme remains near to but always lowers than 0.01. And the corresponding power factor decreases from 1 to 0.22, which implies that the MI model predicts accurately the minimum power needed for RN to relay. The reliability requirement is met and the energy is saved as much as possible. On the contrary, although the error performance of fixed AF scheme is much lower than the target BLER, yet the waste of energy is obvious that RN is always retransmitting with full power. The power efficiency is not optimal. When the SNR of S-D link is higher than -1.5dB, the reliability requirement can be satisfied without cooperation.

As the minimum relay power factor is set to 0.1, the adaptive AF scheme is still better than the no cooperation scheme.

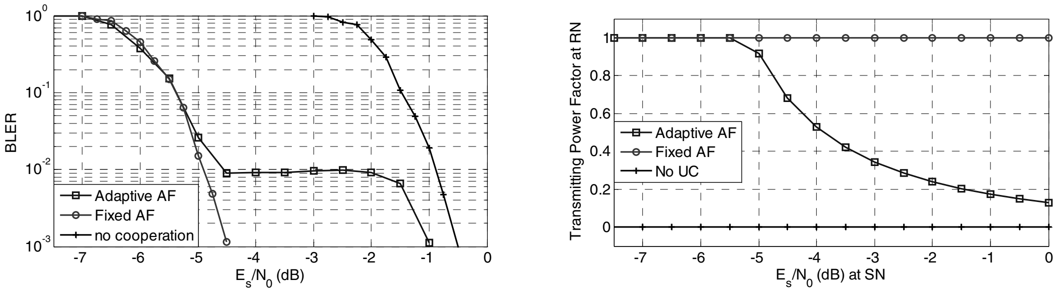

Fig. 3. (a) The error performance comparison; (b) The power efficiency comparison

Acknowledgements

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References

[1] A. Sendonaris, E. Erkip, and B. Aazhang, “Increasing uplink capacity via user cooperation diversity,” Information Theory, 1998. Proceedings. 1998 IEEE International Symposium on, pp. 156, 1998.

[2] J. N. Laneman, and G. W. Wornell, “Exploiting distributed spatial diversity in wireless networks,” in Proceeding of Allerton Conference, 2000.

[3] T. E. Hunter, and A. Nosratinia, “Cooperation diversity through coding,” Information Theory, 2002. Proceedings. 2002 IEEE International Symposium on, pp. 220, 2002.

[4] L. Wan, S. Tsai, and M. Almergn, "A fading-Insensitive Performance Metric for a Unified Link Quality Model," IEEE WCNC, Vol.4, pp. 2110-2114, Apr 2006.

[5] Xiang Chen, et al. The Application of EESM and MI-Based Link Quality Models for Rate Compatible LDPC Codes. in Vehicular Technology Conference, 2007. VTC-2007 Fall. 2007 IEEE 66th. 2007.

[6] Xiang, Chen, et al. The Application of the MI-Based Link Quality Model for Link Adaptation of Rate Compatible LDPC Codes. in Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE. 2008.